THE EFFECTS OF CURRENT DEPRIVATION

ON EXPLORATORY BEHAVIOR

by

Barry Blakley

Approved by:

Chairman, Thesis Committee

Associate Professor of
Psychology

Joyce G. Crouch
Professor of Psychology

Joyce G. Crouch
Chairperson, Department of
Psychology

Richard H. Rupp
Dean of the Graduate School

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Abstract

This study examined the effect of food and water deprivation upon the exploratory behavior of mice. Previous studies of exploratory behavior had been limited to rats and had provided inconclusive results on the effect of deprivation, differences in exploratory behavior due to sex, and different assumptions on exploration due to differing measures of that behavior. There were 20 mice, 10 males and 10 females, which were exposed to four levels of deprivation, 0-hr., 24-hr., 48-hr., and 72-hr., for either food of water deprivation. The two different measures of exploratory behavior were locomotion, the number of units of a checkerboard maze entered in two minutes, and response-latency, the time to leave the entry cage into the maze. By using a 2-between, 1-within analysis of variance and Duncan's Multiple-Range Test, this study provided significant results of an increase in exploratory behavior with deprivation while showing no differences in exploratory behavior due to sex. This study also found a significant correlation between the locomotion and response-latency measures of exploratory behavior.

The Effects of Current Deprivation on Exploratory Behavior

All animals, including man, exhibit an increased amount of activity when certain physiological conditions arise, especially when nutritional needs are not immediately satisfied. Animals might be expected to have some innate tendency to explore their environment when hungry or thirsty, since this tendency would have some survival value, but animals have also demonstrated a willingness to explore their environment without any apparent physiological need. This study pertains to that exploratory behavior.

Studies by Nissen (1930), Warden (1931), and others have ranked the relative strengths of animals' motives with maternal behavior being the strongest, and thirst, hunger, sex, and exploratory behavior being next in order. These relative strengths were obtained from measures of random activity which were brought on by appropriate need states. One of the classic experiments demonstrating exploratory behavior is the one in which rats have refused to eat until their novel environment has been explored, even if under the effects of current deprivation (Zimbardo and Montgomery, 1957).

The purpose of this study is to review some of the literature on such exploratory behavior, to study what effects deprivation of food or water might have upon exploratory behavior, and to account for any differences observed. The information about the effects of hunger and thrist on exploration is somewhat perplexing as the following studies will demonstrate.

The major findings of Zimbardo and Montgomery (1957) on the effects of deprivation and the presence (or non-presence) of a goal object on the consummatory and exploratory behavior of rats in a complex, symmetrical maze, were that food and water deprivation resulted in decrements in exploratory behavior (satiated groups explored more than deprived groups); there was little consistent difference between hunger and thirst groups; and when deprived rats were placed in a novel environment with the opportunity to eat, drink, or explore, they explored for some time prior to initial consummatory behavior.

Montgomery (1953) had previously studied the effects of deprivation on the exploratory behavior of rats on a simple Y maze. The findings then were that deprivation significantly reduced the amount of exploratory behavior with the maximum decrement occurring at 24-hr. for food deprivation, and no noteworthy differences among the groups of 24-, 48-, and 72-hrs. of deprivation. Montgomery, more importantly however, went on to conclude that the commonly held assumption that the amount of exploratory behavior was a positive function of the strength of a primary drive such as hunger or thirst was an over-simplification, and these results were evidence that exploratory behavior was a

primary drive in itself, aroused by external stimuli, which undergoes a decrement in strength when another primary drive is present.

Dashiell (1925) offered evidence which supported the belief that the current physiological condition (e.g., hunger) leads to a "seeking" behavior or activity. His results demonstrated that hungry rats entered more units in his famous Dashiell maze than satiated rats in a one-minute trial.

Campbell and Sheffield (1953) proposed an alternative to the hypothesis that an increased "drive" results in increased activity. Their alternative hypothesis was that drives involved lowering the threshold to an external stimulus. Their results from the study of random activity of rats in a constant environment provided evidence that in fact there is little change in the activity of an animal unless there were some external stimulation. They went on to conclude that the slight rise in general activity of the animals during deprivation was due to their greater sensitivity to minimal stimulus changes in the environment provided. In other words, starvation did not instigate activity, but only lowered the threshold for normal stimuli to increase activity.

Thompson (1953) found no significant difference between the exploratory behaviors on an elevated maze of rats deprived of food for 0-, 24-, and 48-hrs. However, there was a significant interaction between hours of deprivation and sex: exploration of males increased with hours of deprivation, whereas females showed a slight increase with 24-hrs. deprivation, and then a sharp decrease.

When Alderstein and Fehrer (1955) found that rats explored more when deprived than when satiated, the results of studies of deprivation on exploration became equivocal. One important result of their study, however, was that deprived rats explore at a more consistent rate than satiated rats. More recently, Hughes (1965, 1968) and Fehrer (1956) have found increases in exploratory behavior with deprivation.

DeLorge and Bolles (1961) summarize the studies of deprivation on exploratory behavior and outline the current problems by stating:

> . . . some doubt has arisen regarding the generality of Dashiell's findings. Montgomery (1953), and Zimbardo and Miller (1958), using female rats and simple apparatus, found that exploration decreased with increasing hunger. Zimbardo and Montgomery (1957) using both males and females and a somewhat more complex test apparatus, again found decrements in exploration with increasing hunger. Other Es have tried to clarify the basic effects of apparatus complexity and sex on exploration, but the results have been confusing. Thus, Thompson (1953) found an interaction: males increased exploration and females decreased exploration with increasing hunger. Compatible with this are the results of Alderstein and Fehrer (1955) and Glickman and Jensen (1961), using male animals, which included increments in exploration with hunger. The sex variable seems to be a determining factor, females showing positive effect and males negative ones, but it is not that simple. Hall, Low, and Hanford (1960) have recently reported decrements with males; moreover, Carr, Overall, White, and Brown (1959) and Stackhouse, Burns, and Wohlford (1960) found no effect on deprivation and, finally, Zimbardo and Montgomery (1957) found no sex difference. With regard to apparatus complexity, the picture is likewise

> confusing. Complex apparatus (Dashiell, 1925; Alderstein and Fehrer, 1955; Hall, 1960) has yielded mixed findings just as often as has simple apparatus like a Y maze (Montgomery, 1953; Carr et al., 1959; Glickman and Jensen, 1961). In short, the conflicting findings that have been reported cannot be ordered in any simple way on the basis of either the sex variable or apparatus complexity.

Since significant results in studies of exploratory behavior have led to conflicting conclusions, a review of the measures of exploratory behavior and problems inherent in these measures may clarify the issues somewhat. The chief difficulty seems to lie in the definition and observation of exploratory behavior. There are basically three types of measures commonly used in exploration studies: (1) a locomotion measure of the number units of a maze in which an animal travels in a given time, (2) an orderliness measure in which the tendency of the animal to alternate places is noted, and (3) a response-latency measure in which the time taken for an animal to respond to the situation is noted. The use of the response-latency measures has resulted in the more consistent report of sex differences.

Although locomotive exploration is a universal behavior among all animals, it is hard to distinguish exploration as inferred from the number of maze units entered per given unit of time from general activity. Rats maintain their activity level on a periodic basis with certain individual differences despite nutrition or food consumption. These periods may change from a 2-4 hr. cycle to a 1-2 hr. cycle, but animals maintain a periodic nature to their activity despite environmental changes. Female rats will also have an obvious activity rhythm over a period of days rather than hours known as their estrous activity cycle. Although the maximum activity for a rat is correlated with the portion of the estrous cycle known as estrum, or heat, each rat may have an activity cycle peculiar to that individual. Berlyne (1960) and Montgomery (1953) point out that locomotion can serve a variety of functions at different times, and it is not easy to establish the part played by exposure to stimuli. Locomotion may serve as a basic motor exercise and it is also known that there are many variables which affect the mobility of the rat. Campbell and Lynch (1968), Campbell, Smith, Misanin, and Jaynes (1966), and Treichler and Hall (1962) have also postulated that activity while experiencing some form of deprivation may be an attempt to regulate body temperature and any "goal directed behavior," while being deprived is brought about by external (or environmental) stimuli. Another key result from these studies is the significant differences in the effects of deprivation on activity between different individuals. But the more serious difficulty in using locomotion as a measure of exploration is in justifying the conceptual difference between the amount of exploration an animal devotes to his environment as a whole rather than to a particular portion of it. Is a rat that moves rapidly from one set of stimuli to another exploring more or less than an animal that spends a long time in one place before passing on? Are hungry

animals which move on quickly from one novel situation to another equally novel one in search of food exploring more than one which examines an unfamiliar environment to ascertain whether food is available before moving on?

The tendency of an animal to alternate places visited is another measure of exploratory behavior. One representative study of such an exploratory measure was undertaken by Montgomery (1952) who investigated on the relation of exploratory behavior to spontaneous alternation. One key issue in using an orderliness measure is the inability to determine if an animal is moving away from a stimulus or if it is moving toward it. Another problem is using orderliness measures in comparison with the other measures, especially when interacting with a deprivation effect. Montgomery (1953) found that hunger decreased exploration in a Y maze but that it had no effect on the orderliness of exploratory behavior. Montgomery (1954) went on to hypothesize that novel stimulation could serve as a reinforcing agent and an orderliness measure could actually be a measure of learning. Petrinovich and Bolles (1954) found there were differences in training rats deprived of water and rats deprived of food on alternating arms on successive trials. Carr (1959) repeated the earlier results in finding no difference in orderliness in the exploration of deprived and satiated male rats. The end result seems to be that the tendency to alternate arms (orderliness), while having some survival value, is more a component of both the need to explore and the need to find a commodity relevant to its existing need.

The use of response latency as a measure of exploratory behavior has been the most definitive measure used in demonstrating that currently deprived animals will enter a novel environment sooner than a non-deprived animal. Zimbardo and Miller (1958) first identified the potential conflict between tendencies to continue to explore the immediate environment more thoroughly and the tendency to move on to explore the next one. Fehrer (1956) noted that deprived male rats left their home cages sooner for an exploration box than did satiated males. Bolles and DeLorge (1962) found a similar result in trying to replicate Fehrer's results when deprived males left their home cages sooner when they were opened than did satiated males. Hughes (1968) also found that currently deprived rats would enter a novel environment sooner than non-deprived rats. Lester (1967*a*) reported that sex differences had been reported more consistently when response-latency measures had been used. Considering the findings of Thompson (1953) as well as his own, Lester (1967*b*) stated that it appears that female rats explore more when satiated than when deprived, but male rats explore more when deprived than when satiated. Although Richards and Leslie (1962) and Zimbardo and Montgomery (1957) found conflicting results, these results were attributed to the interaction of confounding variables. According to Lester, the effects of sex, although minor

and easily obscured by other variables introduced in the experiment, nonetheless exist.

Despite the inconclusive evidence provided by studies of exploratory behavior, several conclusions appear to be justified. Depending on certain factors and measures of exploratory behavior (e.g., DeLorge and Bolles, 1961, defined exploration as locomotion, window peaking, manipulation, investigation, peering), the evidence, although conflicting at times, seems to be that exploration increases with deprivation. There seems to be a difference according to sex on the effects of deprivation on exploratory behavior (more consistent with response-latency measures) which appears to be that female rats explore more when satiated than when deprived, but male rats explore more when deprived than when satiated. And finally, response-latency measures have also provided more consistent evidence that currently deprived rats will explore novel environments sooner than non-deprived rats.

This study has investigated the effects of deprivation in a rodent species (mice) in an effort to determine the generalizability of findings in experiments using rats. Hughes (1969) studied exploration in three laboratory rodents (mice, rats, and hamsters), and upon finding significant differences concluded that species differences should clearly be considered when describing the relative frequencies of exploratory responses. Glickman and Hartz (1964) reported significant differences between rodent species in the amount of locomotion in an open field. Campbell et al. (1966) studied species differences in activity during deprivation finding significant differences despite similar environments and similar weight-loss functions. So while there is evidence that mice may explore more than rats, before one can fully understand the concept of exploration, findings must clearly demonstrate the specific effects of deprivation upon exploratory behavior, and the extent to which these effects are generalizable to other species.

Secondly, this experiment was designed to study the sex differences in the exploratory behavior of another laboratory rodent. Lester (1967) and Halliday (1966) have proposed a theory of exploration which supposes to explain the sex differences in exploration. It appears that although there has been a recent trend in reporting sex differences in exploratory behavior, these results are not consistent with earlier results. It is believed therefore that the phenomenon should be studied more closely in other animals before being used as supportive evidence for any theory.

Furthermore, recent studies on the effects of deprivation have brought out some interesting differences between the effects of food deprivation and water deprivation. Although thirst has been reported to be the stronger drive (Warden, 1931), in recent studies, water-deprived rats have shown no increase in "normal" activity throughout deprivation but have shown the same amount of activity as food-deprived rats in a novel environment (Campbell et al.,

1966). Glickman and Jensen (1961) also found a significant difference in exploratory behavior for food-deprived rats but not so for water-deprived rats. It appears that the role of hunger vs. thirst has not been clearly determined either, so this study will examine that effect also.

Finally, this experiment will study the relationship between response-latency and locomotion as measures of exploratory behavior. The consistency of response-latency measures in demonstrating that deprived rats will enter a novel environment sooner seems to be the recent trend in exploration studies. If locomotion as measured in units traveled in a novel maze is an accurate measure of exploratory behavior, it should correlate significantly to a response-latency measure for the same animal entering the maze from some neutral environment.

The hypotheses of this experiment (stated as null hypotheses) are as follows: (1) there should be no effect of deprivation upon exploratory behavior, (2) there should be no differences between sex in regard to exploratory behavior, (3) there should be no differences in exploratory behavior according to type of deprivation (food or water), (4) there should be no significant interaction effect, and finally, (5) there should not be a significant correlation between locomotion and response time as measures of exploratory behavior.

Method

Subjects

The Ss were 20 experimentally naive adult mice of mixed strains ranging in age from 60 to 90 days. The Ss were housed in group cages and were tamed prior to the start of the experiment. All Ss were on an *ad libitum* diet until deprivation began.

Apparatus

A maze measuring 24 in. by 24 in. by 8 in. high, divided into nine 8 in. square units with connecting doorways 2 in. wide was used. The maze was constructed of particle board and remained unpainted. The maze was placed on a concrete floor to facilitate cleaning with indirect fluorescent lighting 8 ft. overhead. A standard aluminum cage (6 in. x 10 in.) was used as the entry cage outside the maze. The cage and the maze were wiped clean after each trial. All time was kept by industrial timers. The Ss were identified by a harmless dye applied prior to the experiment.

Procedure

An equal number of males and females were assigned at random to a food or water deprivation group. The groups were thus: MF--male food deprived, FF--female food deprived, MW--male water deprived, and FW--female water deprived. The four groups were tested for durations of 0-, 24-, 48-, and 72-hrs. deprivation. The design was a 2 x 2 x 4 within subjects factorial which was analyzed with a 2-between, 1-within analysis of variance.

Each S was placed in the separate entry cage and allowed to be gentled for one minute outside the maze entrance. At that time the cage door was opened and a timer was started. The S had up to 10 minutes to make a 4-paw entrance into the maze. Once the S had made a complete entry into the maze, the door was shut and the S had 2 minutes to explore the maze. If the S did not enter the maze in 10 minutes, it was removed from the entry cage, gentled again, and then placed in the maze for the allotted 2 minutes. Records were kept of how long it took each S to leave the entry cage and how many units were entered in the two-minute period with an entry considered a complete 4-paw entrance.

Results

Analysis of variance on the locomotion measure of exploratory behavior is presented in Table 1, page 15. The results indicate that under increased deprivation there was a significant change in the number of units entered in two minutes ($F = 5.50$, $p < .002$). There was also a difference in the amount of exploratory behavior according to type of deprivation ($F = 4.50$, $p < .05$). Those animals deprived of food explored more than those animals deprived of water. Finally, no significant interaction effect was shown nor any difference in the amount of exploratory behavior due to sex. Table 2, page 16, shows the means and standard deviations for the locomotion measures. Duncan's multiple-range test was used as a further analysis of the cell-wise differences but found no critical differences at the .05 level.

Table 1

Locomotion Measure

Analysis of Variance				
Source	SS	df	MS	F
Drive	3618.0	1	3618.0	4.50*
Sex	1980.0	1	1980.0	2.42
D x S	871.2	1	871.2	1.07
Error b	13085.9	16	817.9	
Time	3419.6	3	1139.9	5.50**
T x D	1361.3	3	453.8	2.19
T x S	593.7	3	197.9	0.96
T x D x S	1024.2	3	341.4	1.65
Error w	9944.1	48	207.2	

$^{*}p < .05$.

$^{**}p < .002$.

Table 2

Locomotion Measure

Cell Means				
Food Deprivation				
	0-Hr.	24-Hr.	48-Hr.	72-Hr.
Males	46.6	67.4	58.6	80.0
Females	31.8	52.8	99.4	52.4
Water Deprivation				
	0-Hr.	24-Hr.	48-Hr.	72-Hr.
Males	45.2	43.4	44.8	39.0
Females	25.0	38.2	49.8	46.0

Standard Deviations				
Food Deprivation				
	0-Hr.	24-Hr.	48-Hr.	72-Hr.
Males	28.1	11.9	14.3	29.3
Females	14.9	22.8	27.6	24.0
Water Deprivation				
	0-Hr.	24-Hr.	48-Hr.	72-Hr.
Males	7.7	9.1	15.9	12.9
Females	25.2	13.8	14.8	8.8

The analysis of variance for the response-latency measure is presented in Table 3, page 18. These results demonstrated a significant decrease in the amount of time to enter the novel environment with increased deprivation ($F = 11.39$, $p < .001$). These results also indicated a difference, although only significant at the .10 level, between the hunger and thirst groups. The results here also indicated that there was a significant interaction ($F = 2.97$, $p < .05$) between time of deprivation and type of deprivation. Initially, this appears to be a failure to transform the response times into other measures, but Duncan's Multiple-Range Test again demonstrated a significant comparison between the 0-hr. and 72-hr. groups for the .05 level. Results on the analysis of response time further showed no differences on exploratory behavior due to sex. Finally, the correlation between the two measures of exploratory behavior was -.337, a significant correlation ($p < .05$), which indicates that the two measures of exploratory behavior vary together to a slight degree. Table 4, page 19, presents the summary data for the response times (in seconds).

Table 3

Response-Latency Measure

Analysis of Variance				
Source	SS	df	MS	F
Drive	159799.4	1	159799.4	3.18
Sex	3469.4	1	3469.4	0.07
D x S	29834.9	1	29834.9	0.59
Error b	804297.1	16	50268.6	
Time	448089.4	3	149363.1	11.39**
T x D	116921.6	3	38973.8	2.97*
T x S	62609.2	3	20869.7	1.59
T x D x S	62190.5	3	20730.2	1.58
Error w	629350.6	48	13111.5	

$^{*}p < .05$.

$^{**}p < .001$.

Table 4

Response-Latency Measure

Cell Means				
Food Deprivation				
	0-Hr.	24-Hr.	48-Hr.	72-Hr.
Males	128.9	35.6	82.3	18.7
Females	105.9	23.2	26.9	7.6
Water Deprivation				
	0-Hr.	24-Hr.	48-Hr.	72-Hr.
Males	358.9	27.5	52.6	29.5
Females	287.5	246.1	131.0	11.0

Standard Deviations				
Food Deprivation				
	0-Hr.	24-Hr.	48-Hr.	72-Hr.
Males	116.0	64.1	75.5	18.6
Females	128.3	8.4	31.9	8.0
Water Deprivation				
	0-Hr.	24-Hr.	48-Hr.	72-Hr.
Males	232.3	19.5	78.6	20.1
Females	288.0	323.1	262.4	9.0

Table 5

Locomotion Measure

Duncan's Multiple-Range Test

Comparison	Difference	Critical Value
0-hr./24-hr.	13.3	18.4
0-hr./48-hr.	13.5	19.4
0-hr./72-hr.	17.2	20.0
24-hr./48-hr.	0.2	18.4
24-hr./72-hr.	3.9	19.4
48-hr./72-hr.	3.7	18.4

Table 6

Response-Latency Measure

Duncan's Multiple-Range Test

Comparison	Difference	Critical Value
0-hr./24-hr.	137.2	146.4
0-hr./48-hr.	147.1	153.9
0-hr./72-hr.	204.1*	158.6
24-hr./48-hr.	9.9	146.4
24-hr./72-hr.	66.9	153.9
48-hr./72-hr.	57.0	146.4

*Significant at the .05 level.

These results then indicate that: (1) there was a significant difference in exploratory behavior with deprivation both as a measure of locomotion and response latency; (2) deprived mice consistently explored more and sooner than satiated mice; (3) there was no difference in exploratory behavior due to sex; (4) there was a difference between types of deprivation with hungry mice exhibiting more exploratory behavior than thirsty mice; (5) on the response-latency measure, there was a significant interaction between the type of deprivation and the extent of deprivation; and finally (6) the consistent trend of more exploration with deprivation for both the locomotion and response-latency measures was significantly correlated beyond a chance relationship.

Discussion

The major finding of this experiment, that exploratory behavior increases with deprivation, is evidence that exploratory behavior does indeed increase when a primary drive such as hunger or thirst arises. If one recalls that exploratory behavior has been defined as those tendencies an animal, including man, has to explore, to investigate, or in general, to seek out new forms of stimulation and not just those activities which serve to maintain biological well-being, these results may be used to support the contention that an organism does more than just process information; it actively needs and seeks information or stimulation. In other words, these results are evidence of the

emerging view that organisms have a primary drive for exploration. Thus, when another drive such as hunger or thirst is present, it is assumed that this drive becomes complementary to the exploratory drive and, therefore, exploratory behavior will increase. Although this experiment failed to distinguish the relationship between different measures of exploratory behavior, the effects of deprivation evidently facilitates many response categories of exploratory behavior.

The results from this experiment demonstrate no difference in exploratory behavior between sexes. As reviewed before, the results on sex differences in exploration have not been consistent. The evidence from this experiment does not conclusively prove that there are no sex differences in experimental mice, but rather raises a question of what variables were used when sex differences were found. Although it has been stated that sex differences may be minimal and can be easily obscured, it is not clear how to isolate these sex differences. Symons (1973) demonstrated a genetic influence upon certain behavioral measures among inbred mouse strains. It is apparent then that the genetic constitution (as found between sexes) may produce differences at the behavioral level, but these differences have yet to be clearly specified. Perhaps it is best to assume that if there are sex differences in exploratory behavior, they are much more complex than previous results have suggested.

The differences found between food deprivation and water deprivation groups in the number of units of a maze entered are somewhat similar to what Campbell et al. (1966) found when studying species differences in activity during hunger and thirst. Water deprived animals maintained the same level of activity (or a slight decrease) in their living cages but had the same sharp increase in activity as the food deprived animals when presented with an activity wheel. Based on the knowledge that thirst interferes with eating, animals being completely deprived of water, as done in this experiment, are evidently suffering from a decreased food diet also. The differences in the locomotion measure of exploration and the interaction effect on response-latency found for the mice in this experiment could be due to this confounding physiological effect of thirst and hunger. These animals showed the same initial increase in exploration due to deprivation, but then leveled off sooner or showed a slight decrease in exploratory behavior with the onset of the added physiological effect. Although there have been studies which have balanced the psychophysical differences of thirst and hunger, the differences on exploratory behavior have usually not been of significant magnitude to warrant such actions. One important consideration to be taken into account in interpreting these results, however, is the differences between individuals (and groups) on the 0-hr. deprivation level. Individuals of both sexes of the water deprived groups were sharply

different from the others for both the locomotion and response-latency measures, with certain individuals staying in the entry cage for the maximum 10 minutes. This difference may have had an effect on some of the resulting analyses. This experiment failed to account for such a possibility, but this study could not prepare any counterbalancing measures due to limited facilities and resources.

The final result to be discussed is the correlation of the locomotion measure with response-latency. The results for both measures were consistent and significantly correlated. The key issue in studying exploratory behavior remains the definition of and the observation of those behaviors constituting exploration. When one considers that behavior is usually considered the whole of the activities of an animal, it is easy to find fault with locomotion being the index of exploration. Berlyne (1960) suggests one important aspect which is difficult to define and to measure is the "orienting response." Thus, when DeLorge and Bolles (1961) divided exploration into seven exhaustive categories, they still found that deprivation led to an increase in nearly 80 percent of all behaviors observed. The conclusion that they drew, and which is supported by the results of this experiment also, is that while deprivation may be eliciting behaviors that may be either complementary or even competing, the net result of deprivation upon exploratory behaviors is to increase their occurrence. The effect of deprivation is thus consistently an increase in exploratory behavior, an increase which is related across differing measures of behavior.

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